Proceedings of the 2nd African Congress in Tribology

A joint event with

the 3rd Euro-Mediterranean Conference on

Bioengineering, Biomaterials and Biomedicine

ACT2017 – EMC3B

April 16–19, 2017

Marrakesh, Morocco

An Overview of Challenges and Opportunities in the Modeling and Simulation of Refrigerant-Lubricated Gas Foil Bearings

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The worldwide quest for innovative transportation technologies which meet the exigent requirements of the 21st century is significantly characterized by its attention to energy efficiency and environmental sustainability. Particularly in aeronautics and space engineering, an upcoming breakthrough is expected from the further development and promotion of oil-free rotating machinery with high-speed rotors supported by self-acting gas foil bearings (GFBs). Due to the aerodynamic pressurization of the lubricating fluid preventing any solid-to-solid contact between the rotor journal and the bearing sleeve, the use of GFBs permits to overcome yet insurmountable limitations of conventional rolling-element or oil bearings in terms of power loss, wear, speed, temperature, size, weight, and cleanliness. With regard to recent turbocharger or propulsion engine concepts, ambient air is a common and natural choice as the lubricating fluid, whereas it appears much more convenient and straightforward to directly use the surrounding working fluid if GFBs are deployed for vapor-compression refrigeration in applications such as air cycle machines of aircraft [2, 3].

In recent years, research on GFBs has become a topic of remarkable scientific interest with the main focus on computational analysis of mathematical and physical models, given the complexity and costliness of experiments. The computational time being a highly critical aspect in the simulation of fully coupled fluid–structure–rotor interaction models, the lubricant pressure is typically described by a rather simplistic 2D Reynolds equation for compressible ideal gases under isothermal and isoviscous conditions [1, 4, 5]. Moreover, it is often avoided to establish realistic foil structure models which consider local stiffness variations and dry friction energy dissipation, knowing that such elaborate approaches prove to be inapplicable when it comes to a transient analysis of the overall system's nonlinear dynamic response. However, most notably if considering refrigerant-lubricated GFBs under heavy dynamic loading, neither thermal effects upon the fluid behavior [2,3] nor dissipative dry friction within the foil structure [1, 4, 5] can be neglected without introducing substantial inaccuracies. Hence, based on a generalized 3D Reynolds equation, a heat transfer equation, and a gas–liquid phase transition equation, Garcia et al. [3] developed a novel thermo-aerodynamic fluid model, which Bouchehit et al. [2] successfully coupled to an elastic foundation model representing the foil structure.

Focusing mainly on refrigerant-lubricated GFBs, the present contribution discusses arising challenges and opportunities toward the ultimate goal of efficiently simulating rotor dynamics under self-excitation [4] when coupling the thermo-aerodynamic fluid model from [2,3] to dissipative foil structure models similar to [1, 5].

[1] Barzem, L., Bou-Saïd, B., Rocchi, J., and Grau, G. (2013): Aero-elastic bearing effects on rotor dynamics: a numerical analysis. *Journal of Lubrication Science*, **25**(7), pp. 463–478.

[2] Bouchehit, B., Bou-Saïd, B., and Garcia, M. (2016): Static and dynamic performances of refrigerant-lubricated bearings. *Tribology International*, **96**, pp. 326–348.

[3] Garcia, M., Bou-Saïd, B., Rocchi, J., and Grau, G. (2013): Refrigerant foil bearing behavior – A Thermo-HydroDynamic study (Application to rigid bearings). *Tribology International*, **65**, pp. 363–369.

[4] Leister, T., Baum, C., and Seemann, W. (2017): On the Importance of Frictional Energy Dissipation in the Prevention of Undesirable Self-Excited Vibrations in Gas Foil Bearing Rotor Systems. In *Proceedings of the SIRM 2017*, Graz, Austria.

[5] Leister, T., Bard, S., and Seemann, W. (2017): A Minimal Dynamic Structure Model Considering Dry Friction Energy Dissipation in Gas Foil Bearings. In *Proceedings of the GAMM Annual Meeting 2017*, Weimar, Germany.